

# THE *NEXT GENERATION* *SCIENCE STANDARDS* AND THE LIFE SCIENCES

*The important features of life science standards for elementary, middle, and high school levels*

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**P**ublication of the *Next Generation Science Standards* will be just short of two decades since publication of the *National Science Education Standards* (NRC 1996). In that time, biology and science education communities have advanced, and the new standards will reflect that progress (NRC 1999, 2007, 2009; Kress and Barrett 2001).

Just as earlier standards influenced state-level standards, assessments, and science teachers at all levels, so too will the *Next Generation Science Standards* (NGSS).

Using the life sciences, this article first reviews essential features of the NRC *Framework for K–12 Science Education* that provided a foundation for the new standards. Second, the article describes the important features of life science standards for elementary, middle, and high school levels. Finally, I discuss several implications of the new standards. This article extends other discussions of biology and the *Next Generation Science Standards* (see Bybee 2011b, 2012) and other publications for science teachers (Willard et al. 2012).

Core ideas for the life sciences consist of the following: From Molecules to Organisms, Ecosystems, Heredity, and Biological Evolution. The following sections describe the core and component ideas for K–12 life sciences (NRC 2012) in greater detail.

## Disciplinary core ideas for the life sciences

### Core Idea 1: From molecules to organisms: Structures and processes

This core idea addresses the characteristic structures of organisms. Individual organisms also accomplish specific functions to support life, growth, behavior, and reproduction. This core idea centers on the unifying principle that cells are the basic unit of life. This core idea includes the following component ideas.

*Structure and function:* Beginning with cells as the basic structural units of life, organisms present a hierarchy of structural systems and subsystems that perform specialized

functions. A central problem of biology is to develop explanations for functions based on structures and the reciprocal—to explain the complementarity of structures and functions among an organism's systems and subsystems.

*Growth and development of organisms:* As organisms grow and develop their anatomy and morphology (structures), processes from the molecular to cellular to organism-level, as well as behaviors, change in predictable ways. Central to understanding growth and development of organisms are the concepts of cell division and gene expression.

*Organization for matter and energy flow in organisms:* Organisms require matter and energy in order to live and grow. In most cases the energy needed by organisms is derived from the Sun through photosynthesis. As a result of chemi-

## Essentials of A Framework for K–12 Science Education

*A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC 2012) presents fundamental concepts and practices for the new standards and implied changes in K–12 science programs. The *Framework* describes three essential dimensions: science and engineering practices, crosscutting concepts, and core ideas in science disciplines. In this article, the core disciplinary ideas are from the life sciences.

The scientific and engineering practices have been discussed in earlier NSTA publications (Bybee 2011a) and are summarized below.

### Practices for K–12 science curriculum

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The second dimension described in the NRC *Framework* is crosscutting concepts. These too have been discussed in an earlier NSTA article (Duschl 2012) and are summarized here.

### Crosscutting concepts for K–12 science education

1. *Patterns.* Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying the patterns.
2. *Cause and effect: Mechanism and explanation.* Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships and the mechanisms by which they are mediated is a major activity of science.
3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different sizes, times, and energy scales and to recognize proportional relationships between different quantities as scales change.
4. *Systems and system models.* Delimiting and defining the system under study and making a model of it are tools for developing understanding used throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation.* Tracking energy and matter flows, into, out of, and within systems, helps one understand a system's behavior.
6. *Structure and function.* The way an object is shaped or structured determines many of its properties and functions.
7. *Stability and change.* For both designed and natural systems, conditions of stability and what controls rates of change are critical elements to understand.

cal changes, energy is transferred from one system of interacting molecules to another and across different organizational levels from cells to ecosystems.

**Information processing:** Organisms have mechanisms to detect, process, and use information about the environment. That information contributes to an organism's survival, growth, and reproduction.

### Core Idea 2: Ecosystems: Interactions, energy, and dynamics

This core idea includes organisms' interactions with each other and their physical environment. Biologists develop explanations for how organisms obtain resources, how they change their environment, how changing environmental factors affect organisms and ecosystems, how social interactions and group behavior play out within and between species, and how these factors all combine to determine ecosystem functioning. This core idea includes the following component ideas.

**Organisms have mechanisms to detect, process, and use information about the environment. That information contributes to an organism's survival, growth, and reproduction.**

**Interdependent relationships in ecosystems:** An ecosystem includes both biological communities (biotic) and physical (abiotic) components of the environment. Ecosystems continually change due to the interdependence of biotic and the abiotic elements of the environment. As organisms seek matter and energy to sustain life, the interactions may be represented as food webs.

**Cycles of matter and energy transfer in ecosystems:** Interactions among organisms and the physical environment influence the cycling of matter and flow of energy in ecosystems. Plants require light energy for photosynthesis—a chemical reaction that produces plant matter from air and water. As animals meet their need for food,

the chemical elements that make up organisms are combined and recombined as those chemical elements pass through food webs. The cycling of matter and flow of energy through ecosystems conserve matter and energy through the many changes.

FIGURE 1

**An example of a performance expectation for elementary school life sciences with supporting content from the foundation box and connection box.**

3-LS1 From Molecules to Organisms: Structures and Processes		
Students who demonstrate understanding can:		
<b>3-LS1-a. Construct explanations from evidence that life cycles of plants and animals have similar features and predictable patterns.</b> [Clarification Statement: Changes organisms go through during their life form a pattern and can be used to predict what might happen next in a different organism. Reproduction is addressed as just one part of the process of birth, growth, development, reproduction, and death.] [Assessment Boundary: Plant reproduction is limited to flowering plants. Evidence should be provided.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> .		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Constructing Explanations and Designing Solutions</b> Constructing explanations and designing solutions in 3–5 builds on prior experiences in K–2 and progresses to the use of evidence in constructing multiple explanations and designing multiple solutions. <ul style="list-style-type: none"> <li>Use evidence (e.g., measurements, observations, patterns) to construct a scientific explanation or design a solution to a problem. (3-LS1-a)</li> </ul>	<b>LS1.B: Growth and Development of Organisms</b> <ul style="list-style-type: none"> <li>Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles that include being born (sprouting in plants), growing, developing into adults, reproducing, and eventually dying. (3-LS1-a)</li> </ul>	<b>Patterns</b> <ul style="list-style-type: none"> <li>Cyclic patterns of change related to time can be used to make predictions. (3-LS1-a)</li> </ul>
<b>Connections to Nature of Science</b> <b>Scientific Knowledge is Based on Empirical Evidence</b> <ul style="list-style-type: none"> <li>Science findings are based on recognizing patterns. (3-LS1-a)</li> </ul>		
Connections to other DCIs in this grade-level: will be added in future version.		
Articulation of DCIs across grade-levels: will be added in future version.		
Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]		
ELA –		
<b>RI.3.10</b> By the end of the year, read and comprehend informational texts, including history/social studies, science, and technical texts, at the high end of the grades 2–3 text complexity band independently and proficiently. (3-LS1-a)		
<b>SL.4.4</b> Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (3-LS1-a)		
Mathematics –		
<b>MP.3</b> Construct viable arguments and critique the reasoning of others. (3-LS1-a)		
<b>MP.7</b> Look for and make use of structure. (3-LS1-a)		



*Ecosystem dynamics, functioning, and resilience:* Dynamics of ecosystems result from changes in populations of organisms through time and changes in physical environments. The dynamics of ecosystems result in shifts such as changes in the diversity and numbers of organisms, the survival or extinction of species, the migration of species, and the evolution of new species. Changes in ecosystems can result from natural processes and human activity. The resilience of an ecosystem is a function of greater or lesser biodiversity.

*Social interactions and group behavior:* Organisms ranging from unicellular slime molds to humans demonstrate group behavior. Group behavior can be explained by its survival value for individuals.

### Core Idea 3: Heredity: Inheritance and variation of traits

This core idea focuses on the flow of genetic information between generations. It explains the mechanisms of genetic inheritance and describes the environmental and genetic causes of gene mutation and the alteration

of gene expression. This core idea includes the following component ideas.

*Inheritance of traits:* Heredity refers to the processes by which characteristics of a species are passed from one generation to the next. Heredity explains why offspring look like, but are not identical to, parents.

Chromosomes carry the genetic information for a species' characteristics. Each chromosome consists of a single DNA molecule, and each gene is a particular segment of DNA. DNA molecules consist of four building blocks called nucleotides that form a linked sequence. The specific sequence of nucleotides constitutes a gene's information. Through cellular processes, that genetic information forms proteins, which build an organism's characteristics.

*Variation of traits:* Genetic and environmental factors produce variations of traits within a species population. Variation in traits can influence the development, appearance, behavior, and ability of organisms to produce offspring. The distribution of variations of traits in a population is an essential factor in biological evolution.

FIGURE 2

## An example of a standard for middle school life sciences with supporting content from the foundation box and connection box.

MS-LS4 Biological Evolution: Unity and Diversity		
Students who demonstrate understanding can:		
<b>MS-LS4-f. Use mathematical models to support the explanation of how natural selection over many generations results in changes within species in response to environmental conditions that tend to increase or decrease specific traits in a population.</b> [Clarification Statement: Emphasis is on using mathematical models to explain trends based on data for changes in populations over time.] [Assessment Boundary: The assessment should provide evidence of students' abilities to explain trends in data for the number of individuals with specific traits changing over time.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> .		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Developing and Using Models</b> Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to support explanations, describe, test, and predict more abstract phenomena and design systems. <ul style="list-style-type: none"> <li>Develop models to describe unobservable mechanisms. (MS-LS4-f)</li> </ul> <b>Using Mathematics and Computational Thinking</b> Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. <ul style="list-style-type: none"> <li>Apply concepts of ratio, rate, percent, basic operations, and simple algebra to scientific and engineering questions and problems. (MS-LS4-f)</li> </ul>	<b>LS4.B: Natural Selection</b> <ul style="list-style-type: none"> <li>Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population, and the suppression of others. (MS-LS4-e), (MS-LS4-f)</li> </ul> <b>LS4.C: Adaptation</b> <ul style="list-style-type: none"> <li>Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. (MS-LS4-f), (MS-LS4-h)</li> <li>Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS-LS4-f)</li> </ul>	<b>Cause and Effect</b> <ul style="list-style-type: none"> <li>Cause and effect relationships may be used to predict phenomena in natural or designed systems. Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS4-b), (MS-LS4-e), (MS-LS4-f)</li> </ul>
Connections to other DCIs in this grade-level: will be added in future version.		
Articulation of DCIs across grade-levels: will be added in future version.		
Common Core State Standards Connections:		
ELA /Literacy–		
<b>SL.7.5</b> Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-LS4-f)		
Mathematics –		
<b>MP.4</b> Model with mathematics. (MS-LS4-f)		
<b>5.OA</b> Analyze patterns and relationships. (MS-LS4-f), (MS-LS4-d)		
<b>6.EE</b> Represent and analyze quantitative relationships between dependent and independent variable. (MS-LS4-f)		

**Core Idea 4: Biological evolution: Unity and diversity**

This core idea uses “changes in the traits of populations of organisms over time” to explain species’ unity and diversity. Biological evolution is supported by extensive scientific evidence ranging from the fossil record to genetic relationships among species. This core idea includes the following component ideas.

**Evidence of common ancestry and diversity:** Biological evolution results from changing environmental factors and the subsequent selection from among genetic variations in a population that across generations changes the distribution of those characteristics in that population.

Common ancestry and diversity are supported by multiple lines of empirical evidence including the fossil record, comparative anatomy and embryology, similarities of cellular processes and structures, and comparisons of DNA sequences between species. Recent advances in molecular biology have provided new empirical evidence supporting prior explanations for changes in the fossil record and links between living and extinct species.

**Natural selection:** As environments change, organisms with variations of some traits may be more likely than others to survive and reproduce. Genetic variation in a species makes this process of natural selection possible. In time, natural selection results in changes in the distribution of certain traits. That is, selection leads to an increase of organisms in a population with certain inherited traits and a decrease in other traits.

**Adaptation:** Natural selection is the mechanism by which species adapt to changes in resources or the physical limits and biological challenges an environment imposes. In the course of many generations adaptation can result in the formation of new species. If a population cannot adapt due to a lack of traits that contribute to survival and reproduction, the species may become extinct.

**Biodiversity and humans:** Biodiversity is the multiplicity of genes, species, and ecosystems. It provides humans with renewable resources and benefits such as ecosystem services. Biological resources must be used within sustainable limits or there will be detrimental consequences such as ecosystem degradation, species extinction, and reduction of ecosystem services.

The four core ideas for the life sciences have a long history and solid foundation as the basis for the life sciences in school programs (Hurd 1961; Bybee and Bloom 2008; BSCS 1993). These core ideas extend and elaborate those established K–12 science education standards: *National Science Education Standards* (NRC 1996) and *Benchmarks for Science Literacy* (AAAS 1993). The ideas also incorporate the *Science College Board Standards for College Success* (College Board 2009), and the ideas are

consistent with frameworks for national and international assessments.

**From the Framework to standards**

The NRC *Framework* provided guidance for developing standards through 13 recommendations designed to ensure fidelity to the *Framework* and serve as direction for the development of standards. For this discussion the following summarizes the NRC recommendations for standards development.

The standards should:

- ◆ Set rigorous goals for all students.
- ◆ Be scientifically accurate.
- ◆ Be limited in number.
- ◆ Emphasize all three dimensions.
- ◆ Include performance expectations that integrate the three dimensions.
- ◆ Be informed by research on learning and teaching.
- ◆ Meet the diverse needs of students and states.
- ◆ Have potential for a coherent progression across grades and within grades.
- ◆ Be explicit about resources, time, and teacher expertise.
- ◆ Align with other K–12 subjects, especially the Common Core Standards.
- ◆ Take into account diversity and equity (NRC 2012).

Given the criteria and constraints for developing life science standards, a working group of biology teachers and other educators developed standards for the four unifying concepts and component ideas.\* Figures 1 through 3 are example standards for elementary, middle, and high school life sciences, respectively.

The architecture seen in Figures 1 through 3 (pp. 27, 28, and 30–31, respectively) requires clarification. The titles “From Molecules to Organisms: Structures and Processes,” “Biological Evolution: Unity and Diversity,” and “Biological Evolution: Unity and Diversity,” represent one standard each for elementary, middle, and high school life sciences. The standards include the performance expectations in the top portion, identified as “3-LS1-a,” “MS-LS4-f,” and “HS-LS4-b” and “HS-LS4-d” in the three figures, respectively. The performance expectations are formed by combining

\* The NGSS life sciences team, co-chaired by Rodger Bybee and Brett Moulding, included contributions from the following individuals: Zoe Evans, Kevin Fisher, Jennifer Gutierrez, Chris Embry-Mohr, Julie Olson, Sherry Schaaf. Preliminary work for the National Research Council was compiled by Kathy Comfort, Danine Ezell, Bruce Fuchs, and Brian Reiser.

a science and engineering practice, disciplinary core idea, and crosscutting concept.

Immediately beneath the performance expectations, you see the foundation box consisting of three sections, one each for science and engineering practices, disciplinary core ideas, and crosscutting concepts. These three columns present content from the *Framework* and serve as a reference for the performance expectations in the standard. You should note the relationship between “3-LS1-a,” “MS-LS4-f,” and “HS-LS4-b” and “HS-LS4-d” before the performance expectations and at the end of statements in the foundation box. Descriptions in the foundation box answer the questions:

- ♦ What are the essential knowledge and abilities of the performance expectations?
- ♦ What are the specific details of the practices, disciplinary core ideas, and crosscutting concepts that students should know and be able to do?

- ♦ What should be emphasized in the science curriculum and classroom instruction?

The performance expectations are learning outcomes, not instructional activities, and they are the basis for assessments. One should note that along with content in the foundation box, they may be the point of departure for backward design of curriculum instruction (Wiggins and McTighe 2005).

The three examples displayed in Figures 1–3 serve another purpose in this discussion. That purpose is to show a learning progression from elementary school to high school for biological evolution. Although elementary students are not expected to learn the mechanisms of natural selection, they learn about heredity and the variation of traits—concepts fundamental to biological evolution described in greater detail in the middle and high school life science standards.

Here, I note that other standards, for example about interdependent relations in ecosystems, also contribute

FIGURE 3

## An example of a standard for high school life sciences with supporting content from

HS-LS4 Biological Evolution: Unity and Diversity		
Students who demonstrate understanding can:		
<b>HS-LS4-b. Use a model to support the explanation that the process of natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.</b> [Clarification Statement: Emphasis is on the interrelationship of the four factors that result in natural selection. Mathematical models and simulations of changes in distribution of traits in a population at different times may be used.] [Assessment Boundary: Assessment should provide evidence of students' abilities to explain natural selection in terms of the number of organisms, behaviors, morphology, or physiology factors having a direct effect on survival and reproduction as well as ability to compete for limited resources. Mathematical models may be used to communicate the explanation.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> .		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Developing and Using Models</b> Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and explain relationships between systems and their components in the natural and designed world. <ul style="list-style-type: none"> <li>Use multiple types of models to represent and support explanations of phenomena, and move flexibly between model types based on merits and limitations. (HS-LS4-b)</li> </ul>	<b>LS4.B: Natural Selection</b> <ul style="list-style-type: none"> <li>Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. (HS-LS4-b),(HS-LS4-c)</li> </ul> <b>LS4.C: Adaptation</b> <ul style="list-style-type: none"> <li>Natural selection is the result of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-b)</li> </ul>	<b>Cause and Effect</b> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-b),(HS-LS4-d),(HS-LS4-e)</li> </ul>
Connections to other DCIs in this grade-level: will be added in future version.		
Articulation of DCIs across grade-levels: will be added in future version.		
Common Core State Standards Connections:		
ELA /Literacy–		
<b>RST.9–10.7</b> Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-LS4-b),(HS-LS4-c)		
Mathematics –		
<b>MP.4</b> Model with mathematics. (HS-LS4-b)		
<b>F.LE</b> Construct and compare linear, quadratic, and exponential models and solve problems. ( HS-LS4-b)		



to an elementary student's conceptual foundations for biological evolution.

## From standards to curriculum and instruction

From the late 1980s to the early 2000s, teachers of K–12 science and the larger science education community have witnessed an era of standards-based reform. Basically, the idea is to develop clear, comprehensive, and challenging goals for student learning. Review, for example, the aforementioned guidelines for developing the *Next Generation Science Standards*. Beyond learning goals, the implicit assumption is that standards would result in greater alignment among other components of the educational system—curriculum, instruction, assessments, and the professional development of teachers.

In 2001, Elementary and Secondary Education Act (ESEA) legislation—No Child Left Behind (NCLB)—

established assessment as an emphasis in the educational system. This shift in emphasis has significantly influenced the systems' components. Assessment has been a primary concern of educators, and curriculum and instruction have been secondary, at best. This shift to NCLB and priorities of English language arts and math has had the unintentional consequence of reducing or eliminating science in elementary schools. I believe we have gone directly from standards to assessments without addressing curriculum and instruction as the teaching and learning connection.

Relative to the *Next Generation Science Standards*, I am particularly concerned about questions science teachers frequently ask: Where are the curriculum materials that will help me implement the standards in my classroom? And will assessments change? These are both critical questions. There are several initiatives relative to assessment or NGSS, but few discussions of new instructional materials.

## the foundation box and connection box.

HS-LS4 Biological Evolution: Unity and Diversity		
Students who demonstrate understanding can:		
<b>HS-LS4-d. Construct an explanation based on evidence for how natural selection, genetic drift, gene flow through migration, and co-evolution lead to populations dominated by organisms that are anatomically, behaviorally, and physiologically adapted to survive and reproduce in a specific environment.</b> [Clarification Statement: Emphasis is on quantitative evidence as the basis for clarifying the difference among various processes of adaptation within populations. Data on specific environmental differences and selection for/against traits should be used. Environmental factors may include ranges of seasonal temperature, climate change, acidity, and light.] [Assessment Boundary: The assessment should measure students' abilities to differentiate types of evidence used in explanations.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> :		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
<b>Constructing Explanations and Designing Solutions</b> Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific knowledge, principles, and theories. <ul style="list-style-type: none"> <li>Apply scientific reasoning, theory, and models to link evidence to claims to assess the extent to which the reasoning and data support the explanation or conclusion. (HS-LS4-d)</li> <li>Construct and revise explanations based on evidence obtained from a variety of sources (e.g., scientific principles, models, theories, simulations) and peer review. (HS-LS4-d)</li> <li>Base causal explanations on valid and reliable empirical evidence from multiple sources and the assumption that natural laws operate today as they did in the past and will continue to do so in the future. (HS-LS4-d)</li> </ul>	<b>LS4.B: Natural Selection</b> <ul style="list-style-type: none"> <li>The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. (HS-LS4-d),(HS-LS4-c),(HS-LS4-e)</li> </ul> <b>LS4.C: Adaptation</b> <ul style="list-style-type: none"> <li>Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-d),(HS-LS4-c)</li> </ul>	<b>Cause and Effect</b> <ul style="list-style-type: none"> <li>Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS4-b),(HS-LS4-d),(HS-LS4-e)</li> </ul> <hr/> <b>Connections to Nature of Science</b> <b>Scientific Knowledge Assumes an Order and Consistency (Regularity) in Natural Systems</b> <ul style="list-style-type: none"> <li>Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (HS-LS4-d),(HS-LS4-a)</li> </ul>
Connections to other DCIs in this grade-level: will be added in future version.		
Articulation of DCIs across grade-levels: will be added in future version.		
Common Core State Standards Connections:		
ELA /Literacy–		
<b>WHST.9–10.2</b> Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-LS4-d), (HS-LS4-e), (HS-LS4-a)		
<b>WHST.9–10.4</b> Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (HS-LS4-d), (HS-LS4-e), (HS-LS4-a)		
<b>WHST.9–10.9</b> Draw evidence from informational texts to support analysis, reflection, and research. (HS-LS4-d), (HS-LS4-e), (HS-LS4-a)		
<b>SL.9–10.2</b> Integrate multiple sources of information presented in diverse media or formats (e.g., visually, quantitatively, orally) evaluating the credibility and accuracy of each source. (HS-LS4-d),(HS-LS4-e),(HS-LS4-a)		

*When science teachers at all levels K–12 ask—“Where are the materials that help me teach to the standards?”—the educational system must have a concrete answer. The instructional materials may be adapted from current programs, provided by states, or developed by organizations.*

reform and assessment-dominated results. When science teachers at all levels K–12 ask—“Where are the materials that help me teach to the standards?”—the educational system must have a concrete answer.

The instructional materials may be adapted from current programs, provided by states, or developed by organizations. They may come as hardback books, e-books, or other electronic forms; but, they must be available. At a minimum, model units are needed. Arguing for a coherent curriculum based on the standards is not new. Indeed, there is a long history of curriculum serving an essential role in science teaching. If there is no curriculum for teachers, I predict the standards will be implemented with far less integrity than intended by the *Framework* and those who developed the *Next Generation Science Standards*.

## Conclusion

The *Next Generation Science Standards* likely will influence K–12 science teaching for at least a decade, longer if recent history is any indication. This article uses the life sciences as the context for discussion of important content, some challenges, and several opportunities faced by K–12 teachers of science. ■

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I cannot emphasize enough the need for clear and coherent curriculum and instruction that connects the *Next Generation Science Standards* and assessments. Curriculum materials will be the missing link if they are not developed and implemented. The absence of a curriculum based on the new standards will be a major failure in this era of standards-based

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